

No. 20 How To Find the Defective
Part with a Voltmeter

RADIO SERVICING METHODS



NRI TRAINING

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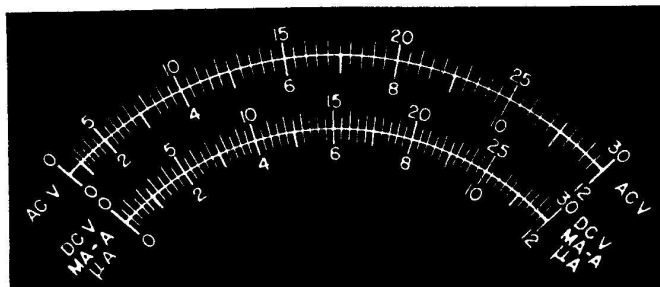
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How To Find the Defective Part with a VOLTMETER

LIKE the ohmmeter, the voltmeter is one of the basic radio servicing instruments. The professional serviceman uses both, for each can make tests that the other cannot. In this RSM Booklet, you will learn how a voltmeter can be used by itself and with an ohmmeter to locate defective *circuits* and *parts*. (Locating defective *stages* with a voltmeter will be taken up in a later Booklet.) Only the standard voltmeter found in most multimeters will be considered; the vacuum-tube voltmeter will be treated elsewhere.

Voltmeter Characteristics. As you know, a voltmeter is a milliammeter in series with a fixed resistor of known value. When this combination is connected across a voltage source, a current flows through the meter, causing a deflection. Since this current depends on the value of the source voltage and on the resistance, we can determine the source voltage by Ohm's Law ($E = I \times R$). Therefore, it is possible to mark the meter scale in terms of voltage instead of in current units.

In fact, that is basically how all voltmeters are made. Each also is usually equipped with some means of changing the value of the resistance (called the "multiplier resistance") in series with the meter; this permits the voltmeter to have several ranges.

Voltmeters are rated by their sensitivities as well as by their ranges—the smaller the current necessary to

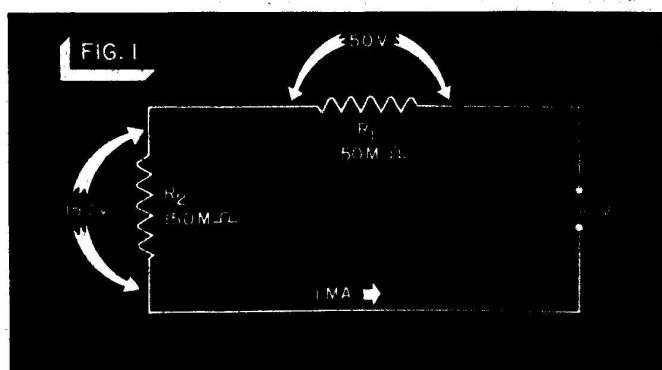
cause a certain meter deflection, the more sensitive the meter. Sensitivity is commonly expressed by the term "ohms-per-volt." The ohms-per-volt rating of a meter can be determined by dividing the total multiplier-meter resistance by the voltage range. Thus, if a meter has a 10-volt range and a total resistance of 10,000 ohms, its ohms-per-volt rating is 10,000 divided by 10, or 1000 ohms-per-volt. The higher the ohms-per-volt rating, the greater the meter sensitivity.

The meters used in the early days of radio required large currents to give readable deflections. Very low sensitivities, such as 60 to 200 ohms-per-volt, were common. Today, however, practically all servicing instruments are rated somewhere between 1000 ohms-per-volt and 25,000 ohms-per-volt.

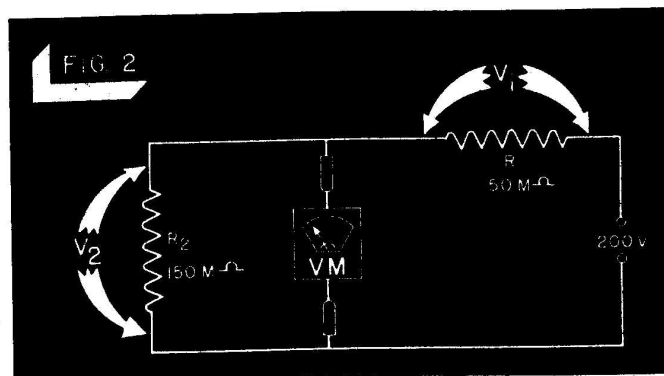
► To show why meter sensitivity is important, let's suppose we have a circuit like the one shown in Fig. 1. With 200 volts applied, a current of 1 ma. will flow, and the voltage drops across the resistors will have the values shown. Now let's suppose we connect a voltmeter across R_2 , as shown in Fig. 2. Will we read 150 volts?

No—for now the resistance of the voltmeter is in parallel with R_2 , and the combination has a total resistance less than the value of R_2 . Therefore, the circuit voltage will divide differently—more voltage will be across R_1 than is shown in Fig. 1.

► Let's suppose we have three voltmeters with 200-volt ranges, one having a sensitivity of 150 ohms-per-volt, another 1000 ohms-per-volt, and the third 20,000 ohms-



2



per-volt. Table 1 shows what will happen in each case when we make the measurement shown in Fig. 2.

The total resistance of the 150 ohm-per-volt meter is 30,000 ohms. When this is connected in parallel with R_2 , the parallel combination will have a total resistance of about 25,000 ohms. The voltage will divide in the ratio of the resistance of this parallel combination to the total resistance in the circuit. Therefore, V_2 , as indicated by the voltmeter, will be about 67 volts, and there will be 133 volts across R_1 .

Now let's repeat the same measurement with the 1000

TABLE I

METER OHMS VOLT	150	1000	20,000
TOTAL METER RESISTANCE FOR 200 V RANGE (OHMS)	30,000	200,000	4,000,000
COMBINED METER- R_2 RESISTANCE (OHMS)	25,000	86,000 (APPROX)	144,500 (APPROX.)
V_2 (VOLTS)	67	127	148
V_1 (VOLTS)	133	73	52
TOTAL I (MA.)	2.66	1.47	1.0 ⁺

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ohm-per-volt meter. This meter's resistance is 200,000 ohms, which, in parallel with R_2 , makes a combined total of approximately 86,000 ohms. Now the V_2 voltage will be about 127 volts, and the voltage across R_1 will be 73 volts.

The 20,000 ohm-per-volt meter has a total resistance of 4,000,000 ohms. When it is connected in parallel with R_2 , the V_2 voltage will be 148 volts, and 52 volts will be found across R_1 .

From this, you can see that connecting any meter across part of a circuit changes the circuit conditions, with the result that the voltage indicated by the meter is lower than the voltage that appears across that part when the meter is not present. However, a high-resistance meter has less effect than a low-resistance meter, and so gives a reading closer to the voltage that will actually be present when the meter has been removed. Therefore, when you want to learn fairly accurately what the normal voltages in a circuit are, use a high-sensitivity voltmeter if the circuit contains high resistance. (If the circuit resistances are low, any meter will do.)

► This does not mean that the readings obtained in a high-resistance circuit with a 1000 ohm-per-volt meter, for example, are useless. They may be perfectly satisfactory as long as you realize that the meter affects the readings. When set manufacturers give voltage readings in their service information, they usually specify the sensitivity and range of the meter used. If you use a different sensitivity or a widely different range, don't be alarmed by even considerable differences between the listed readings and those you obtain, as long as your readings are reasonable. For that matter, most difficulties that occur in radio receivers upset the voltages so radically that you can easily tell when the reading is abnormal.

Now let's see how to use a voltmeter in servicing.

HOW TO MEASURE SUPPLY VOLTAGES

Since the electrode voltages applied to the *amplifier tubes* are always d.c. (except for the filament voltage), we shall devote most of this RSM Booklet to the problem

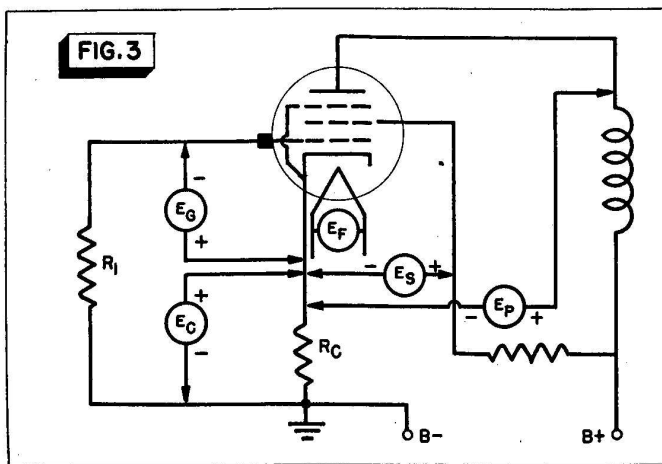
of making d.c. voltage measurements.

There are two very important rules to remember when you are using a d.c. voltmeter:

1. The voltmeter will read up-scale only when current flows through it in the proper direction. Therefore, all meters have colored test probes. It is standard practice to apply the *red* test probe to the positive side of the circuit and the *black* probe to the negative side. Should your meter read down-scale when you connect it, merely interchange the test probes.

2. If you connect the voltmeter between points where the voltage is much higher than the range of the instrument, you will bend the meter pointer (at least) and may even burn out the meter coil. It is easy to avoid this—always start with a very high voltage range first, and switch to lower ranges only after you are sure that the lower range can handle the voltage.

Where To Put the Test Probes. As you know, voltage is measured between *two* points that are different in potential. Therefore, the receiver must be turned on, and the test probes must be touched to the two points between which you wish to measure. The logical point of reference for the negative side of the circuit of an amplifier tube is the cathode. As shown in Fig. 3, connecting the voltmeter between the cathode and any other element of the tube will indicate the supply volt-



age for that element. (The filament is an exception in this case—we will discuss filament voltage measurements when we take up the a.c. voltmeter.) Thus, meter connection E_G measures the grid bias voltage (the voltage between the control grid and the cathode), and meter connection E_C measures the cathode voltage (the voltage between the cathode and B—). Incidentally, these may be very nearly the same if grid resistor R_1 has a low value, and the voltmeter has a high sensitivity. However, if R_1 has a high resistance, it will act as a voltage divider with the meter E_G so that E_G indicates a far smaller voltage than actually exists across E_C .

In some receivers, resistor R_C will not be present, and the cathode will be connected directly to the chassis (B—). In this case all measurements can be made with respect to the chassis; touch the negative voltmeter probe to the chassis, and the positive probe to the other element where you want to make the measurement. If the cathode bias resistor is used, however, you cannot measure the grid bias voltage by connecting a voltmeter between the control grid and the chassis. The reading will be zero because there is normally no d.c. voltage across resistor R_1 . In a.c.-d.c. receivers, the chassis may not be a part of the electrical circuit. If not, make your measurements with respect to the cathode of the tube in the stage under test whether or not a cathode bias resistor is used.

INTERPRETING YOUR MEASUREMENTS

Knowing what your measurement means is just as important as knowing how to make it. To figure out the meaning of the voltage measurements you make, a thorough understanding of voltage distribution is necessary. The distribution of voltage in a circuit follows Kirchhoff's Voltage Law, which says that the voltage rise in a complete circuit must equal the sum of the voltage drops. The voltage rise is the source voltage (the output of a battery or a power pack): a voltage drop is the voltage that appears across a resistive part in the circuit.

A fundamental voltage distribution circuit is shown in Fig. 4. A voltmeter may be connected across the

source E to measure the source potential, or across the parts R_A or R_B to measure their respective voltage drops. Supposing some defect exists in this circuit, let's see what we can find from voltage measurements. Say we find the R_B voltage is: 1, zero; 2, lower than normal; or 3, higher than normal.

► If the voltage across R_B is zero, other measurements may show:

1. No voltage across E or across R_A . This indicates a source defect.
2. Full source voltage across R_A . This means either that R_A is open or that R_B is shorted.

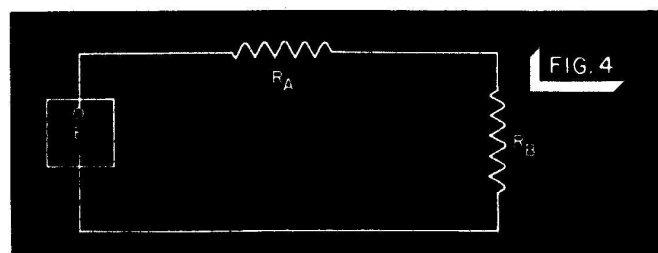
► If the voltage across R_B is lower than normal, but not zero, we may find:

3. Lower-than-normal voltages across E and across R_A . This indicates a source defect.
4. Higher-than-normal voltage across R_A , E voltage normal. This means either R_A has increased in resistance or R_B has decreased.

► Finally, if the voltage across R_B is higher than normal, we may find:

5. Higher-than-normal voltage across E and across R_A . Again, this indicates a source defect.
6. Lower-than-normal voltage across R_A , E voltage normal. This means either that R_A has decreased in resistance or R_B has increased.

► Notice the one fault with the voltmeter check. In cases 2, 4, and 6, you cannot tell exactly which of *two* troubles exists—your readings have merely eliminated other possibilities. In most cases of this kind, you will use an ohmmeter to show which of the two possibilities actually exists.



► The basic circuit shown in Fig. 4 occurs again and again in practical radio circuits. For example, let's consider the power supply in Fig. 5. We may consider the power transformer and rectifier tube as the source of voltage. In this case, the speaker field L_{11} becomes comparable to the series part R_A of Fig. 4, and C_{19} and all the tube circuits connected across it correspond to R_B of Fig. 4.

If the entire power supply up to C_{19} is all right, you can consider the voltage across C_{19} to be the source of voltage for each tube circuit. In this case, the parts in series with the plates, screen grids, or other elements correspond to R_A , and the tubes correspond to R_B . For example, in the plate circuit of the 6F6 output tube, if the voltage across C_{19} is considered the source voltage, then the primary of transformer T_2 corresponds to R_A , and the plate-cathode resistance of the tube corresponds to R_B . Each other plate circuit can be considered in the same way.

Considering parts this way, all the conditions we described in the basic circuit of Fig. 4 are possible in each of the practical circuits of Fig. 5. Let's take some examples.

ZERO VOLTAGE

One measurement of voltage across C_{19} will tell whether the B power supply is in good condition or not. If normal voltage is found, you need make no further measurements in the power supply circuit and can go right on to tube circuits. However, let's first see what to do if no voltage is found across C_{19} .

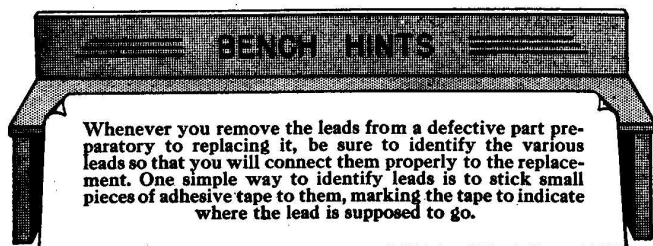
Power Supply Defects. If you measure *no voltage* across C_{19} , check the voltage between the filament of the

rectifier tube and the chassis. If you measure a voltage here, there may be an open in the speaker field L_{11} or a short circuit between B+ and B- (C_{19} shorted, for example). In this case, use an ohmmeter to check the continuity of the speaker field, and check for a short circuit across C_{19} . (Turn off the receiver before you use the ohmmeter!)

If you find no voltage between the filament of the rectifier tube and the chassis, the trouble may be in the power transformer or in the rectifier tube, or C_{18} may be short-circuited. Since the last is the most usual trouble, use your ohmmeter to check this condenser next. (A short circuit in C_{18} will cause the rectifier tube to overheat; its plates may even turn red.) If C_{18} is O.K., use your a.c. voltmeter (we will explain how later) to measure the voltage between each plate of the rectifier and the chassis. Lack of voltage may mean a burned-out high voltage winding, particularly if the tube filaments light up. If normal voltage is measured, the rectifier tube may be defective. However, if none of the tube filaments light up, make certain that voltage is available at the power line outlet by measuring it with your a.c. voltmeter. Also, unplug the set and check for continuity through the line switch and primary of the power transformer with an ohmmeter.

Zero Plate Voltage. Now let's suppose we find normal voltage across C_{19} , but that some tube has no plate voltage. This means there must be an open in the plate circuit or a short circuit across it. For example, a lack of voltage between the chassis and the triode plate terminal of tube 3 may be the result of an open in R_7 , a short circuit in condenser C_{15} , or a tube or socket defect that grounds the plate terminal of the tube. An ohmmeter check should be made across R_7 to determine whether it is open, or from plate to chassis to determine if there is a short circuit.

One point of interest—you might find voltage between the *chassis* and the plate of tube 4, but no voltage between the plate and the *cathode* of the same tube. Since, as the diagram shows, your first reading is actually across both R_{10} and the tube, and the second is across only the tube, finding voltage on the first reading



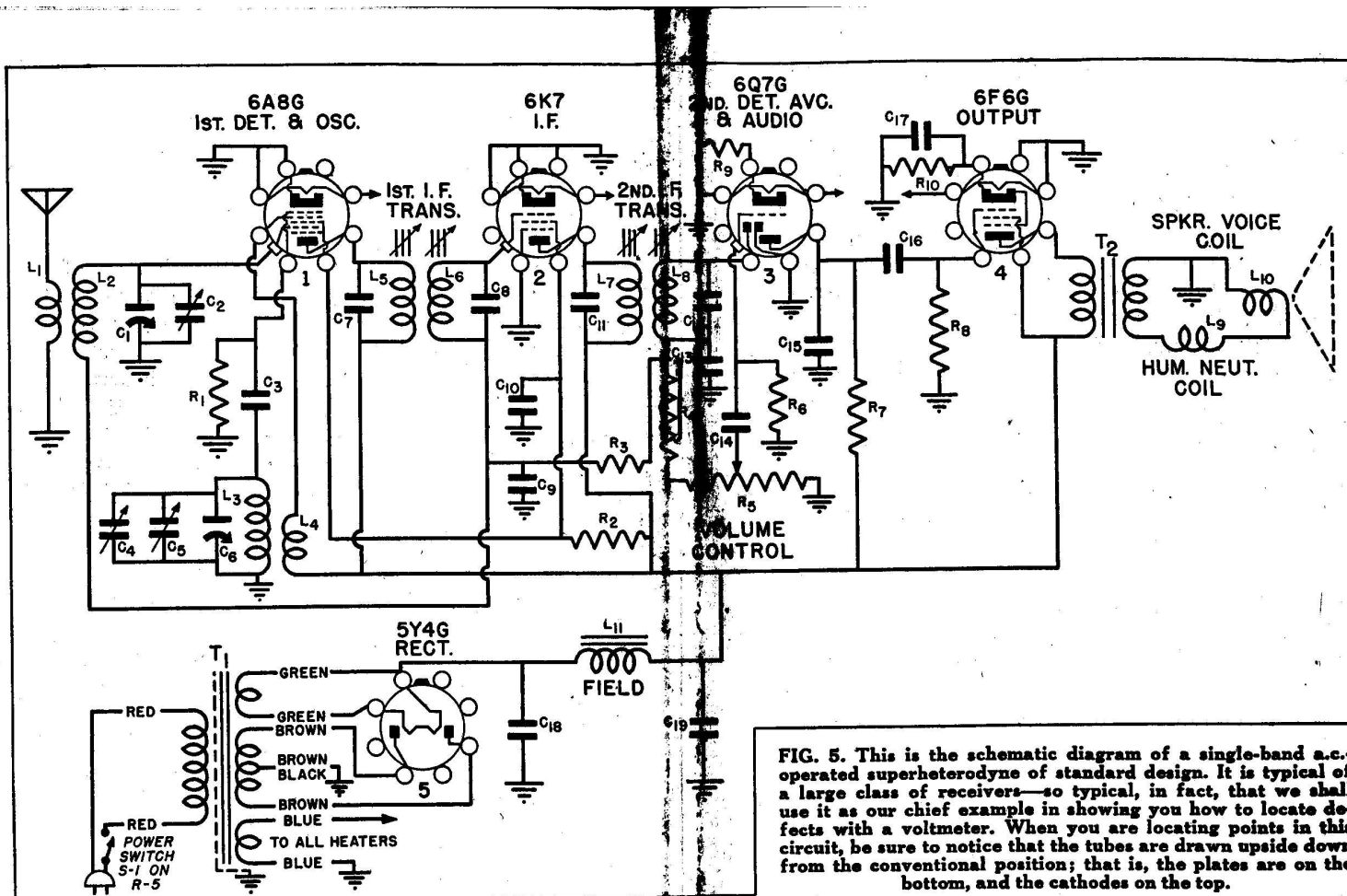


FIG. 5. This is the schematic diagram of a single-band a.c.-operated superheterodyne of standard design. It is typical of a large class of receivers—so typical, in fact, that we shall use it as our chief example in showing you how to locate defects with a voltmeter. When you are locating points in this circuit, be sure to notice that the tubes are drawn upside down from the conventional position; that is, the plates are on the bottom, and the cathodes on the top.

but not on the second means R_{10} is open. You can check on this by connecting the positive voltmeter probe to the cathode of the tube, and the negative probe to the chassis. If the resistor is open, a very high voltage will be found across it. Here is a case where a measurement between plate and cathode proves more valuable than one between plate and chassis.

VOLTAGES LOWER THAN NORMAL

Just where you should start to measure voltage in a radio receiver depends on what the complaint is and on

how far you have localized the trouble. If you have localized the trouble to some particular stage, take your readings in that stage first. On the other hand, if you have not localized the trouble to a stage, then you may measure either plate voltages or the voltage at the output of the power supply first.

Usually it is best to check the power supply first. You will have to check it anyway if you find a plate voltage is low, since a reduced source voltage is a likely cause for a low plate voltage, so you might as well get the power supply measurement over with at once.

Power Supply Troubles. If the voltage across C_{19} is low, check the voltages across C_{18} and across the speaker field. Should the speaker field voltage be unusually high, and should the voltage across C_{19} be *far* lower than that across C_{18} , then probably C_{19} is leaky, or there is a partial short circuit (or leakage path) across the B supply. There is also a chance that the speaker field resistance has increased; check this by turning off the receiver and measuring the field resistance with an ohmmeter. (Incidentally, the field resistance increases as the field heats up: some circuit diagrams list the field resistance cold, whereas others give the hot value, so there may be some variation between your measurement and the listed value.)

► The voltage across C_{19} may be pulled below normal if the output tube draws excessive current. This will increase the voltage drop across the speaker field and also across the primary of transformer T_2 . An upset of the tube bias could cause this increased current. For example, if condenser C_{17} short-circuits, it will short-circuit bias resistor R_{10} , removing bias from the tube and making it draw far more plate current than normal. To check for this short circuit, measure the bias voltage across R_{10} by connecting the positive terminal of the voltmeter to the cathode of tube 4, and the negative terminal to the chassis. If there is no voltage, then C_{17} must be short-circuited.

The bias for tube 4 can also be upset by leakage in condenser C_{16} or by gas in the tube. Either of these conditions will cause a current flow through R_8 in such a direction that the grid end of R_8 is made positive. To check for this, place the positive terminal of the voltmeter on the grid of the tube, and the negative terminal on the chassis. You should get no reading. If you do get a reading, then either condenser C_{16} is leaky, or tube 4 is gassy. To determine which of these is at fault, pull out tube 4. (This can be done only in a standard a.c. receiver.) If the voltage across R_8 disappears when the tube is out of the socket, then the trouble is gas in tube 4. On the other hand, if the voltage still remains, then condenser C_{16} is leaky. (In a.c.-d.c. receivers, you can-

not pull out the tube. Instead, unsolder one lead of the coupling condenser. Now if the voltage disappears, the condenser is leaky, but if it remains, the tube is gassy.)

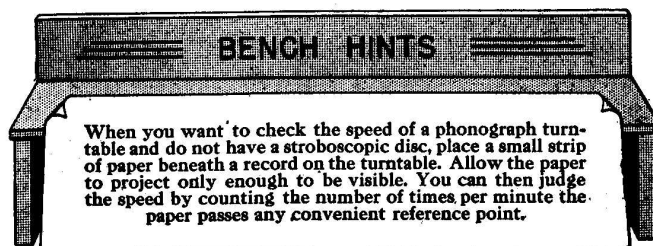
Always check the output stage first before suspecting others. Other stages cannot usually draw enough current to affect the power supply much unless a complete short circuit occurs in one of them.

► If the field voltage is below normal, and the other voltages are low also, then the trouble is not caused by excess current drawn from the power supply unit. In this case, check the rectifier tube. Then, substitute another condenser for C_{18} . Loss of capacity, increased leakage, or development of a high power factor in the input filter condenser are the most frequent causes of low d.c. supply voltage.

However, if a new condenser and a good rectifier tube do not clear up the trouble, then check the power line voltage. Finally, consider the possibility that the power transformer is defective.

HIGH VOLTAGES

There are not many defects that will cause most or all voltages to be far higher than normal. High power-line voltage, of course, can cause this condition. You will also find high voltages if some other serviceman has installed a replacement power transformer that has a higher output than the original. These, however, are rather rare causes; the most probable cause of the existence of high voltages is some defect that reduces the current flow through the speaker field L_{11} . A lowered current through this field reduces the voltage drop across it, and therefore makes more voltage available for the plates and screen grids of the tubes.



Since the output tube normally draws most of the current that passes through the field, suspect the output stage first if you find abnormally high voltages. The tube may be defective, or its bias resistor R_{10} may have opened and thus reduced or cut off the plate current. If so, there will be considerably less current flowing through the speaker field, and the plate voltages on all tubes (except the rectifier) will be high.

Once in a great while you may find that the speaker field is shorted. This will cause all plate and screen voltages to be high; the set, of course, will be dead or very weak, since the speaker will not be operating properly. ► As we said before, your readings may appear high if you are using a meter with a higher sensitivity than specified. Table 2 gives the voltages listed by the manufacturer for the receiver shown in Fig. 5. Notice that a 1000 ohm-per-volt meter is specified. If you use, say, a 20,000 ohm-per-volt meter, the plate-to-chassis voltage for tube 3 will be higher than the listed value.

TABLE 2				
TYPE	PLATE	SCREEN GRID	CONTROL GRID	FILAMENT
6A8 DET.	210V	135V	0V	6.3V (AC)
6A8 OSC	210V	----	---	-----
6K7	210V	135V	0V	6.3V (AC)
6Q7G AMP	100V	----	0V	6.3V (AC)
6F6G	190V	210V	0V	6.3V (AC)
5Y4G	PLATE 1 OR 2, 282V	----	---	5V (AC)

The manufacturer's literature gives the following information in addition to this table of voltage measurements: The above measurements are all made to chassis. Measurements made with set tuned to quiet point, volume control set at minimum, using 1,000 ohm-per-volt meter, having ranges of 10, 50, 250, and 500 volts. (Use nearest range above the specified measured voltage.) All the above values should hold within approximately $\pm 20\%$ for 115 volt, 25-60 cycle supply.

However, the readings in the other circuits should be close to the values listed. Therefore, you should not assume that your higher-than-normal reading indicates trouble unless you have reason to suspect that tube 3 is defective or that its bias resistor R_6 is open.

What Is Normal Voltage? Determining whether a voltage is high, low, or normal is sometimes difficult. First there is the matter of meter sensitivities we just mentioned. You can assume that if your meter is more sensitive than the one the manufacturer lists, your readings will be higher than his readings. On the other hand, if your meter is less sensitive, your readings will be lower than his in any circuit containing considerable resistance.

You can check the general agreement of your readings with those listed by making measurements in the power output stage, where the resistances of all parts associated with the power output plate and screen grid circuits are very low. Readings made in this stage with any service multimeter having a sensitivity of 1000 ohms-per-volt or higher should be close to the values listed in the manufacturers' tables.

By "close," we mean within $\pm 20\%$. This is the tolerance usually specified by manufacturers (see Table 2). Therefore, if the voltage is listed as 250 volts, you can consider any reading between 200 and 300 volts to be reasonable unless the operation of the receiver definitely proves otherwise. This wide permissible variation is another reason why it is sometimes difficult to be sure if a voltage is high or low.

GENERAL RULES

As you become experienced, you will develop your own general servicing procedure. Whether you use an ohmmeter or a voltmeter more will be largely a question of your own preferences—because, as you have probably noticed by now, it is very often possible to use either instrument to locate the same defect. There will be times, however, when you must use a voltmeter; and, when you do, be sure to keep the following general rules and precautions in mind:

1. Always know what you intend to measure.

2. Know where to put your probes—refer to a tube chart to locate the various tube socket terminals.

3. Start out by using a voltmeter range that will measure the highest voltage that could exist in the circuit. Switch to a lower range only when you find it is safe to do so.

4. Don't make measurements to the chassis until you know that continuity exists between the chassis and the cathode of the tube whose circuits are being tested.

5. When you get an abnormal reading, look at the diagram and figure out the possible causes of the trouble. Then make tests that will prove or disprove your conclusion.

A.C. VOLTAGE MEASUREMENTS

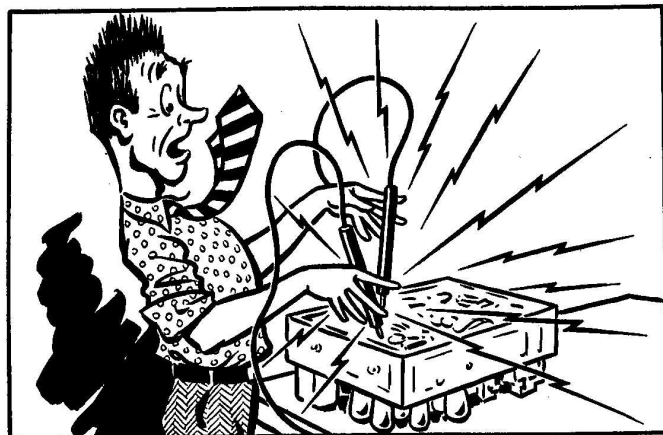
Normally, a serviceman reserves his a.c. voltmeter for use as an output meter when aligning the receiver. (We will tell you all about this when we take up receiver alignment.) However, the a.c. voltmeter may also be used to measure the filament voltage, the high voltage supplied to the plates of the rectifier tube, and the power line voltage, even though none of these measurements are made very often.

In practically all service multimeters, the same meter is used for both a.c. and d.c. voltage measurements; a rectifier is switched into the circuit to make the meter read a.c. Most a.c. voltmeters have sensitivities of 1000 ohms-per-volt, which is entirely satisfactory for all purposes where a.c. voltage readings are made. The meter always has several ranges.

To measure the power line voltage, simply insert the test probes into the socket outlet. Be sure your meter is set to an a.c. range greater than 115 volts.

You can measure the high plate voltages of the rectifier tube by checking between each plate and the set chassis (or B—, if the chassis is not a ground). This voltage is high—frequently as much as 400 volts—so be sure to use a high-voltage meter range and be careful not to touch the bare test probes with your hands while making the measurement.

Tube filament voltages are measured directly across



BE CAREFUL when you make voltage measurements in the power supply—don't allow your probes to touch each other—don't touch the uninsulated parts of the probes.

each tube filament. (Incidentally, you do not have to worry about polarity in any of these measurements; as long as the meter is connected across the a.c. voltage you want to measure, the meter will read up-scale.) Generally speaking, the only reason why a filament voltage is incorrect is that the filament resistance has changed. In the standard a.c. receiver using a power transformer, like that shown in Fig. 5, you cannot detect a change in filament resistance by making a voltage measurement. All the tube filaments are in parallel, and the voltage you measure will be that of the filament winding of the transformer.

However, filament voltage measurements are sometimes useful on battery receivers and on a.c.-d.c. receivers. For example, in the a.c.-d.c. receiver shown in Fig. 6, the tube filaments are all in series, and their voltage drops add to equal the line voltage value. If the resistance of some one tube filament increases, the drop across that tube filament will increase, and the drops across the other tube filaments will decrease. If the tube does not burn out, you can find this trouble by measuring the filament voltages down the string. Conversely, if a filament resistance decreases, the drop across that tube will decrease, and the drops across the others will in-

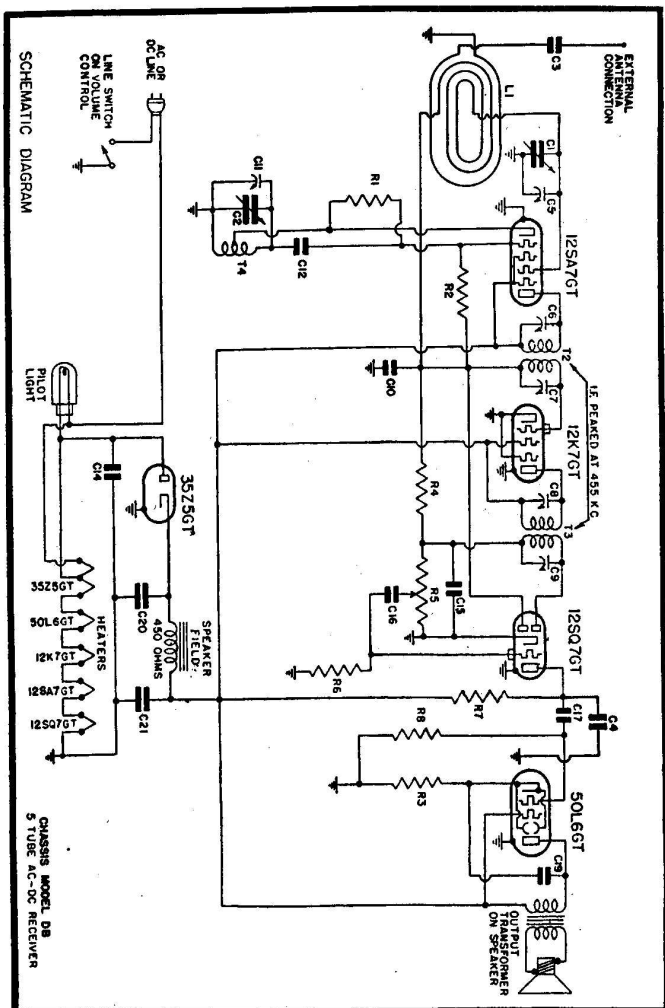


FIG. 6. This is a typical a.c.-d.c. receiver. Many midget and small table-model sets use this circuit or one much like it.

crease. This condition, too, can be found by voltage measurements if none of the other tubes burn out.

This trouble is more likely to occur in a high-voltage filament such as is used in the 50L6 (50 volts) and the 35Z5 (35 volts). These filaments are made by folding

the filament wire back and forth, and it is possible for a loop or two of this folded filament to short-circuit. As you just learned, this may raise the filament voltage on other tubes and may perhaps cause one of the other tubes to burn out.

► The circuit shown in Fig. 7 is unusual in that the filaments of the tubes are in series, but they are operated from the d.c. plate current of the output section of the 70L7 tube when the set is connected to a power line. The only exception is the filament of the 70L7 tube itself, which operates from the a.c. power line voltage. Therefore, you must use an a.c. voltmeter to measure the 70L7 filament voltage, and a d.c. voltmeter to measure any of the other filament voltages.

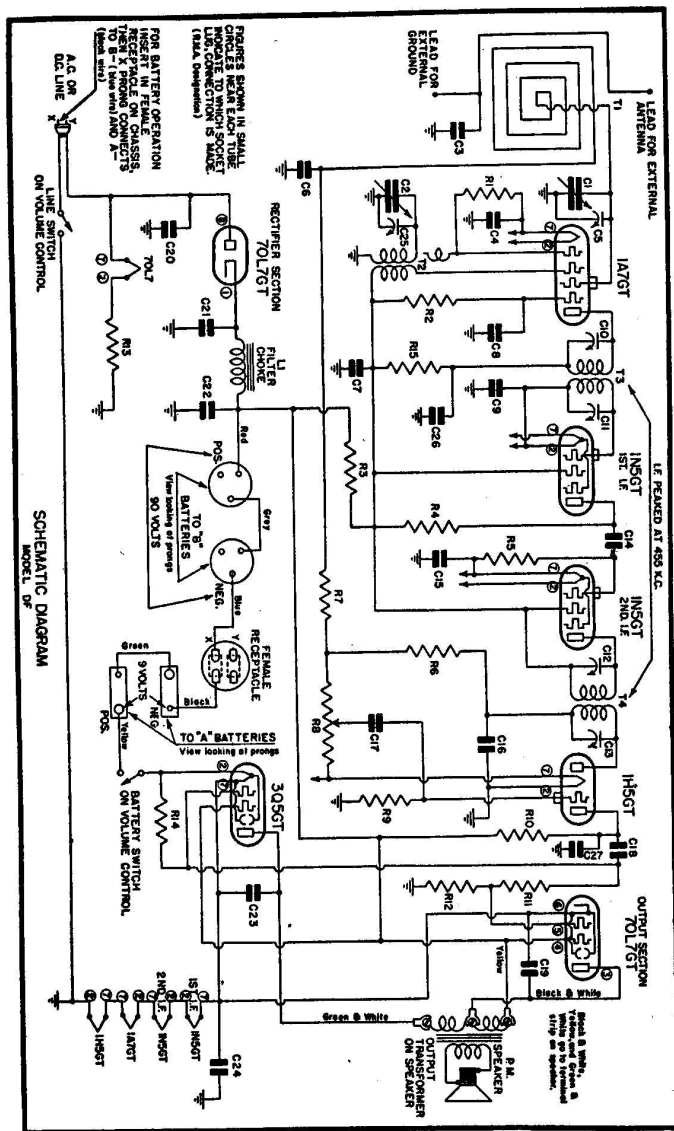
Incorrect filament voltages may be caused in this set even if the filaments do not change in resistance. Notice that the 70L7 tube filament is in series with a resistor, R_{13} . If R_{13} changes in resistance, the voltage drop across the 70L7 tube filament will also change (increasing if the resistance decreases). When the set is operated from a power line, a change in the plate current of the 70L7 tube will change the drops across the filaments of the other tubes. The drops will increase if the plate current increases. (Gas in the 70L7 tube or leakage in condenser C_{18} will upset the bias and cause an increase in plate current.)

When this receiver is operated from batteries, however, the 70L7 tube is not used; the 3Q5 becomes the output tube, and the tube filaments all operate from the A battery. Filament voltages will then be normal if the battery is in good condition and the filaments remain constant in resistance.

NRI PRACTICAL TRAINING PLAN

Continuing now with the NRI Practical Training Plan, carry out the procedure given below on the receiver you have obtained for practical experience.

Measure All Electrode Voltages. Insert the receiver power cord plug into an a.c. wall outlet, turn on the set, set the volume control at its maximum setting (no station tuned in), and measure each d.c. electrode voltage with respect to the cathode (or with respect to the chas-



sis if the voltage values in your service information are given that way). Record each measured value. Compare your readings with those given by the manufacturer so that you can see the results of parts variations and meter sensitivity differences.

Measure also the total rectified d.c. output voltage of the rectifier tube by testing between the rectifier cathode (+) and the center tap of the power transformer secondary (—).

Be sure to use a high range first on all measurements.

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